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The Blockchain as Enabling Technology for Energy Communities.

A Review on the Potentials of the Blockchains and the Importance of the Legislative Framework in the Energy Sector.

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Introduction

Price Waterhouse Coopers 20th CEO survey revealed that 70% of CEOs interviewed consider the speed at which technological change is happening as a huge concern. Top of the list of such technologies was blockchain, which is the most significant digital disruption expected in the next five years[1].

As we are going to see during this dissertation, blockchain is not just Bitcoin. Virtual currency is, in fact, just one of its numerous possible applications.

For now, let us just mention that the blockchain technology allows you to send any data securely, drastically cutting the chain of intermediaries, and thus allowing a secure exchange of data between people, without having to use third-party means[2]. (Tapscott, 2016).

Furthermore, a well-designed blockchain not only reduces intermediaries, but also reduces costs, increases speed, improves transparency and traceability of many business processes[3]. (PwC Global Blockchain Survey: PwC).

Hence, blockchain finds application in many different sectors. From the financial services to transport and logistic, passing through healthcare, insurance, the automotive sector and the public one. The public sector, particularly, was found to be the sector in which the blockchain technologies will have the highest "impact"

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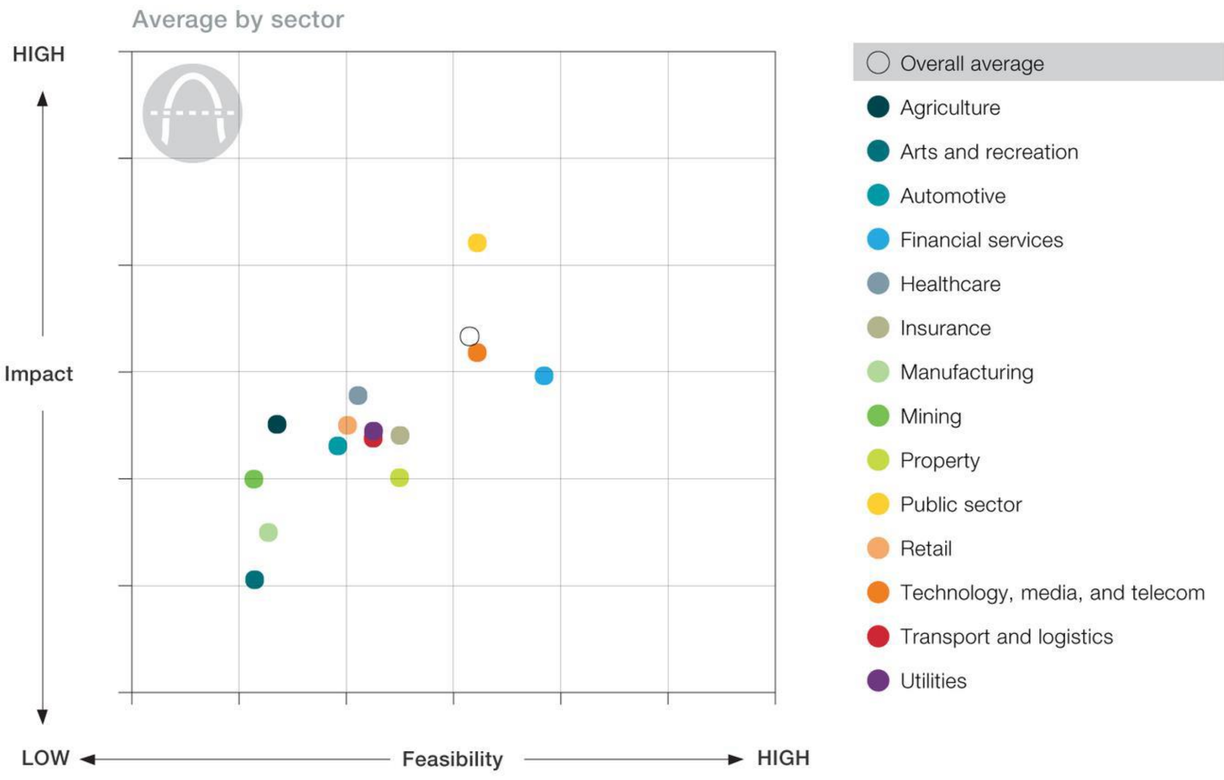
[1] PricewaterhouseCooper. (2017). *20th CEO Survey: 20 years inside the mind of the CEO... What's next?*
[2] Tapscott, D., & Tapscott, A. (2016). Blockchain revolution: how the technology behind bitcoin is changing money, business, and the world. Penguin.
[3] Hileman, G., & Rauchs, M. (2017). Global blockchain benchmarking study. Cambridge Centre for Alternative Finance, University of Cambridge, 122.

and a high level of "feasibility". Among the other sectors with high level of "impact" and "feasibility", we find the financial sector and the technology, media and telecommunication sector.



(Source: McKinsey&Company):

The sector of the utilities presents an average level of feasibility and impact, however we support the thesis that the blockchain technologies, though the use of effective policies aimed at liberalising the markets, could have a much greater impact in this sector. In order to support this view, we will show the case of energy communities in Italy, presenting how the blockchain technologies, paired with a proper legislative structure, may have a disruptive impact even in the utilities sector.

To support our idea, chapter one describes the blockchain technologies, giving a comprehensive description of the technology and its mechanisms, but without falling into useless details. There we will explore the concept of smart contract as well.

As we are going to see understanding the functions of a smart contracts is mandatory in order to understand how and why the blockchain technologies are adaptable for the utilities sector.

Chapter two will analyse the blockchain technologies under a doctrinal approach. We will in facts question ourselves whether the blockchain technologies may be framed into the General Purposes Technologies (GPTs) or not.

As we are going to see, falling into this classification is of particular importance in for the diffusion and large-scale adoption of a technology.

In chapter three we will finally introduce the energy sector, presenting its state of the art in Europe and in Italy. We will introduce the concept of energy communities as well and we will describe their regulatory framework. In the second section of the chapter three we will present some data and analytics of the possible diffusion of the energy communities.

Sharing our view with the one from the study by the “Politecnico di Milano”, we support the idea that the two variables that can play a role in the future importance of the energy communities are the favourable evolution of the legislative framework and of enabling technologies.

The scope of this work, in facts, is to identify the blockchain technologies as the enabling technology par excellence when speaking about energy communities and to push a faster acceptance by the Italian Parliament of the Renewable Energy Directive (RED II).

In Italy, in facts, the only form of self-consumption allowed is the exchange from a single plant to a single final consumer (one to one), preventing the diffusion on energy communities.

Our idea is that Italy risks losing an important challenge and a significant opportunity to create an excellence pole in the niche of energy communities. We are talking about the possibility, that has arisen in recent years, of partnering with third party vendors for the furniture of smart grids[4]. (Davis, 2018)

In the last chapter we will present how actually the blockchain technologies will impact the energy communities offering a direct link between energy suppliers and energy consumers. The blockchain, in facts, is set to transform the energy sector through two ways: develop a decentralized energy supply and transaction system, providing a decentralised storage of transaction data, increasing security and ensuring greater independence from a central authority and help to make payments via cryptocurrencies.

[4] Davis, R. The Evolution of the Smart Grid. Third Party Vendors (Mar 15, 2018)

I. THE BLOCKCHAIN TECHNOLOGIES

At this point, since we already mentioned some of the most important features of the Blockchain technology, appears mandatory to proceed with a simple but comprehensive description of what the Blockchain technologies are. In the following pages we will describe how they work, their history and implications.

1.Introduction

The blockchain technologies were introduced by Satoshi Nakamoto (according to many just a pseudonym hiding a group of people) with his article “Bitcoin: A Peer-to-Peer Electronic Cash System”, during the 2008.

Even if Bitcoin was the first application of the blockchain technologies, those are two distinct systems.

Meanwhile bitcoin is a cryptocurrency –basically, a form of electronic cash different from fiat[5] money– the blockchain technology is a digitized, distributed and decentralized ledger[6]. (Beck, Müller-Bloch, 2017)

"Blockchain technology is a decentralized database that stores a registry of assets and transactions across a peer-to-peer network. It's basically a public registry of who owns what and who transacts what. The transactions are secured through cryptography, and over time, that transaction history gets locked in blocks of data that are then cryptographically linked together and secured. This creates an immutable, unforgeable record of all of the transactions across this network. This record is replicated on every computer that uses the network." (Warburg, 2016)

Blockchain is not an easy concept to understand and the technology beneath it is complicated as well. In order to have a good understanding of it and of its potential, strengths and weaknesses, it is important to describe, in general terms, the key processes involved.

The blockchain is a distributed and cryptographically secure Ledger for managing transactions over peer-to-peer networks. The main features of the blockchain

[5] Fiat money is government-issued currency that is not backed by a physical commodity, such as gold or silver, but rather by the government that issued it. The value of fiat money is derived from the relationship between supply and demand and the stability of the issuing government, rather than the worth of a commodity backing it as is the case for commodity money. Most modern paper currencies are fiat currencies, including the U.S. dollar, the euro and other major global currencies. The word "fiat" comes from the Latin and is often translated as the decree "it shall be" or "let it be done."
[6] Beck, R., & Müller-Bloch, C. (2017). Blockchain as radical innovation: a framework for engaging with distributed ledgers as incumbent organization.

technologies are the immutability of the register, the traceability of transactions and security based on cryptographic techniques[7]. (Swan, 2015).

In other words, blockchain is a database in which data is not stored on a single computer but on multiple machines connected to each other, called nodes, which allows the exchange on the Internet of information and different types of values, such as payments, transactions related to the exchange of goods and services or information related to contracts (Smart Contract).

In the Italian legislation, Law no. 12 of 11 February 2019, Art. 8 ter, Technologies based on distributed registers and smart contracts[8]:

> "*Technologies based on distributed registers" are defined as those technologies and computer protocols that use a shared, distributed, replicable, simultaneously accessible, architecturally decentralized register on cryptographic bases, such as to allow the registration, validation, updating and archiving of data both in clear and further protected by cryptography verifiable by each participant, which cannot be altered or modified*".

[7] Swan, M. (2015). Blockchain: Blueprint for a new economy. " O'Reilly Media, Inc.".

[8] https://www.gazzettaufficiale.it/atto/serie_generale/caricaDettaglioAtto/originario?atto.dataPubblicazioneGazzetta=2019-02-12&atto.codiceRedazionale=19G00017&elenco30giorni=true

While a blockchain is inherently distributed (meaning that many parties hold copies of the register), it is not inherently decentralized. Whether a blockchain is centralized or decentralized simply refers to the rights of the participants on the ledger and is therefore a matter of design.

2.“Blockchain is a Digital Ledger”

A ledger is the principal book or computer file for recording and totalling economic transactions. Its task is, basically, to register information.

This is an old concept, in facts, in ancient history were used paper registers, now we use database. Thanks to the blockchain technologies we will use ledgers.

The digital ledgers in the blockchain, as the name suggests, are structured as a chain of blocks, every block registers information or programs (smart contracts).

It is possible to add new blocks, it is impossible, instead, modify or remove blocks that were previously added to the chain. Every blockchain is formed by a chain of blocks. Nevertheless, their design, the amount, and kind of information they can memorize differs, depending on their purpose.

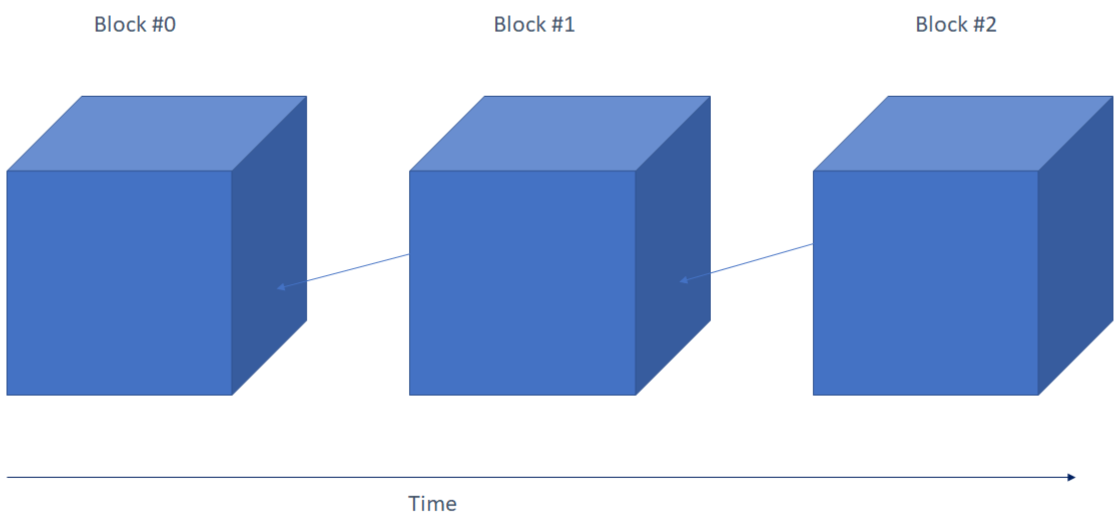


Figure 1 The chain of blocks of a Blockchain.

To ensure their immutability and safety there are cryptography and consensus protocols.

Every block contains a mathematical proof, generated through cryptography, that ensure its sequentially. The first block is called genesis block.

The connection between blocks is generated through a cryptographic function (cryptographic hash function) which creates an indissoluble mathematical link between them.

2.1 The Hash Function

It is a mathematical algorithm that maps data of arbitrary size (often called the "message") to a bit string of a fixed size (the "hash value", "hash", or "message digest") and is a one-way function, that is, a function which is practically infeasible to invert[9]. (Halevi, Krawczyk, 2006).

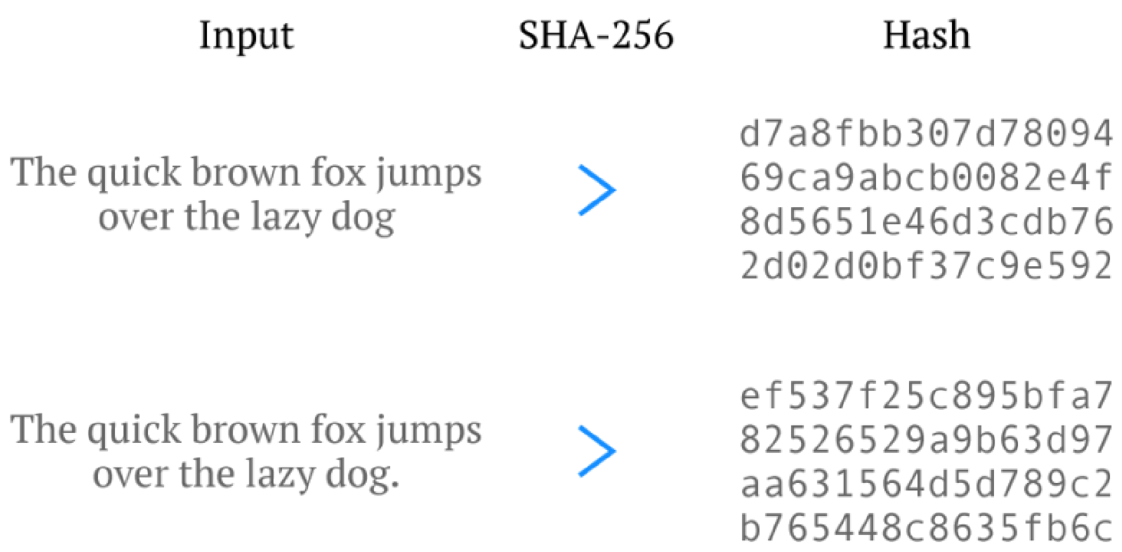
The input of a hash function can be everything: a pdf file, an mp3 etc. etc., but the output, called “hash”, will always have a fixed number of bits.

Keep in mind that:

1) The same input produces always the same output, the hash. The hash is a line of letters and numbers.
2) Even the lightest change of the input produces a drastic change in the output.

[9] Halevi, S., & Krawczyk, H. (2006). Randomized Hashing and Digital Signatures.

3) It is a unidirectional function. Ideally, the only way to find a message that produces a given hash is to attempt a brute-force search of possible inputs to see if they produce a match or use a rainbow table of matched hashes[10].



Example of a Hash Function.

As you can see, the input differs just for one punctuation mark, nevertheless the resulting hashes are completely different between each other.

Since a small change in the input totally changes the output, comparing hashes is much easier and faster than comparing entire files.

[10] Schneier, Bruce. "Cryptanalysis of MD5 and SHA: Time for a New Standard". Computerworld. Retrieved 2016-04-20. Much more than encryption algorithms, one-way hash functions are the workhorses of modern cryptography.

Imagine that you need to check if two copies of the same book are identical. Now imagine that the two copies differ just for the position of a comma. It would be almost impossible. With a digital version of these books and with their hash, we could be able to compare simply the hashes.

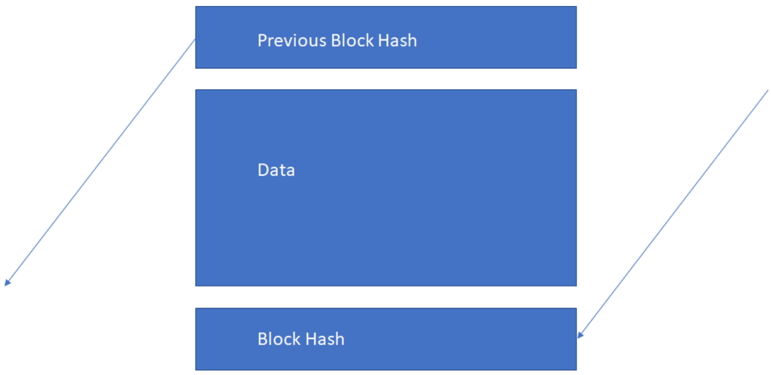


Figure 2The structure of a block.

For every new block the hash of the previous block is used as input for the new block. As a result, if someone tries to modify, delete or add information in any block of the chain, he would modify the hash of that block and, therefore, the hashes of all the subsequent blocks.

2.3 The Blockchain Network

One of the key aspects of the blockchain technologies, as we said in previous paragraphs, is decentralization. Thanks to the blockchain, in facts, everyone is able to trade information and value without relying on a central institution[11].

In order to do so, a blockchain must be distributed on a network. We can define a network as a set of computers connected that exchange information through communication channels, such as the Internet. Every machine connected to the network is a Node.

Here a question arises: since every computer (node) is subject to dysfunction or external attack, how can a blockchain keep the promise of letting any two willing parties to transact in a straight line with each other without the need for a trusted third party?

The answer lies in the fact that every node of a blockchain must agree on a single state. This process is called consensus and it ensures a common, unambiguous ordering of transactions and blocks and guarantees the integrity and consistency of the blockchain across geographically distributed nodes[12] (Baliga, 2017).

The two main actors in this process are full-nodes and miners. In the following pages we will explain better what they are and how they work.

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[11] In the case of monetary transactions, the purpose of the blockchain is to allow transactions without the need to go through a bank. This was the idea and the dominant ideology behind the most famous blockchain, that of the bitcoin, as well as the reason why the blockchain was created.

[12] Baliga, A. (2017). Understanding blockchain consensus models. In Persistent.

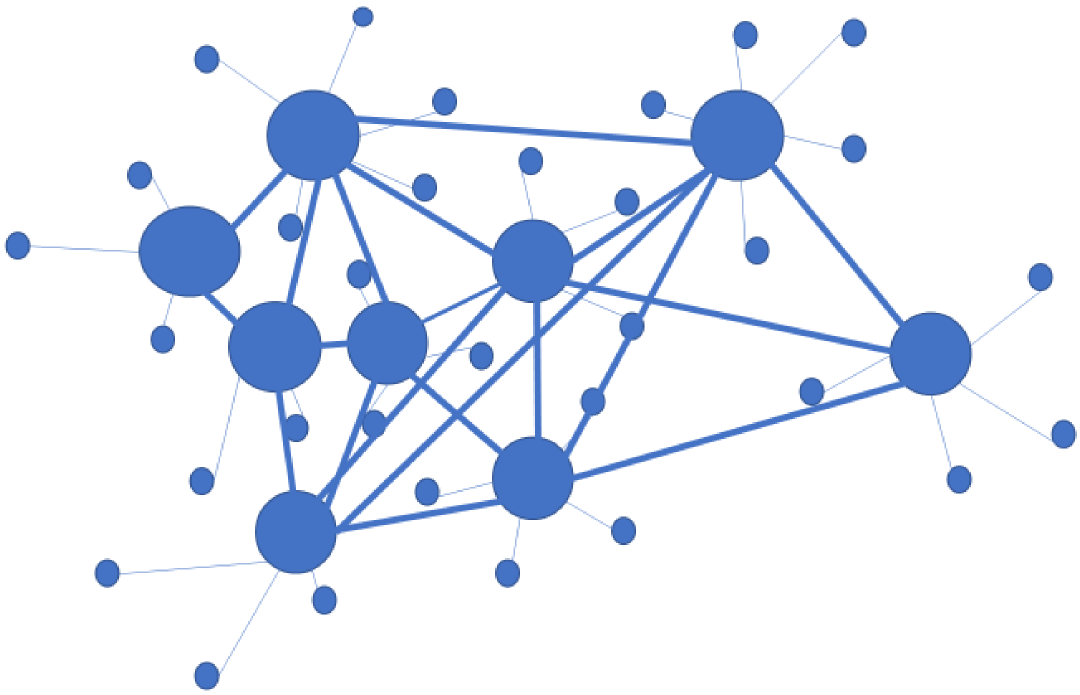


Figure 3The Network of a Blockchain

Nevertheless, reaching consensus in a distributed and decentralized network remains a complex problem.

2.4 Nodes

Each machine connected to the network of the blockchain is a node. It is possible to make a distinction between:

Full-Nodes: it downloads and stores locally a complete copy of the blockchain and controls that every transaction and every block follow the rules defined by the system. Whenever an anomaly occurs, the block, or the transaction, would be refused, even if judged valid by any other node in the network.

Light-Nodes: it does not store the entire blockchain, so it does not have the ability to verify the correctness of the data independently. Hence, it needs to receive the data it needs from a trusted node (a full node).

This is the type of node typically used by the average user.

2.5 Centralization and Decentralization

Although the blockchain, by its very nature and definition, is a decentralized network in terms of both the type of network and the type of authority, it is logically centralized.

Recall that the information is distributed and possibly replicated in the nodes of the network (decentralized network) and that no authority has control by making all nodes equal and not having the possibility of preventing any action (decentralized authority).

Despite these characteristics, as we said above, a blockchain has a centralized logic: its status must always be accepted and by each participant to ensure that it functions properly. Therefore, there is just one and only state on which everyone agrees, more versions cannot exist, as would happen in a logically decentralized network.

2.6 Public and Private Blockchain

In the previous pages, we talked about a kind of blockchain that has:

- a **decentralized architecture**
- a **decentralized authority**
- and a **centralized logic**

When we referee to blockchain, in facts, we usually talk about this kind of blockchains, that are referred to be “permissionless”.

However, it is important to know that we can also design a so-called private blockchain, or “permissioned” blockchain.

Although public blockchains have unique properties, those can make them not ideal in some contexts, such as, for example, in the industrial environment.
We distinguish, utterly private blockchains and the so-called *consortiums*, in the first ones the control and the authority is concentrated in a single entity, removing all the decentralization and all advantages of the technology, in the latter, instead, the control and authority is distributed among the participants of the network previously chosen. In this case, the blockchain is only as reliable as the actors chosen for the process are.

2.7 Consensus and Mining

Computer and softwares are not perfect systems, they can, for example, crash or be hacked. If we then we connect several computers together, the risk that the system may crash, or be hacked, increases. Each computer is thus a weak point.

We have previously talked about the security of the blockchain. If a blockchain is composed, basically, by (weak) computers, how is it possible to ensure its security?

The answer has to be found in that process called consensus.

Despite the inherent uncertainty, in fact, the nodes of a blockchain must come to an agreement on each individual state.

> *Consensus is a general agreement between the members of a given group (in this case the nodes of the Blockchain), each of which has a part of the decision-making power. In a Blockchain consent is an agreement on what happened and holds the only possible truth about the current state of the Blockchain*[13].

We can say that the consent of a Blockchain is the guarantor of the trust we place in this system.

[13] Zheng, Z., Xie, S., Dai, H., Chen, X., & Wang, H. (2017, June). An overview of blockchain technology: Architecture, consensus, and future trends. In *2017 IEEE International Congress on Big Data (BigData Congress)* (pp. 557-564). IEEE.

2.7.1 The Byzantine Generals Problem

> "*In Byzantine General problem, a group of generals who command a portion of Byzantine army circle the city. The attack would fail if only part of the generals attack the city. Generals need to communicate to reach an agreement on whether attack or not. However, there might be traitors in generals. Traitor can send different decisions to different generals. This is a trustless environment. How to reach a consensus in such an environment is a challenge. It is also a challenge for Blockchain as the Blockchain network is distributed.*[14]"

[14] Zheng, Z., Xie, S., Dai, H. N., Chen, X., & Wang, H. (2018). Blockchain challenges and opportunities: A survey. International Journal of Web and Grid Services, 14(4), 352-375.

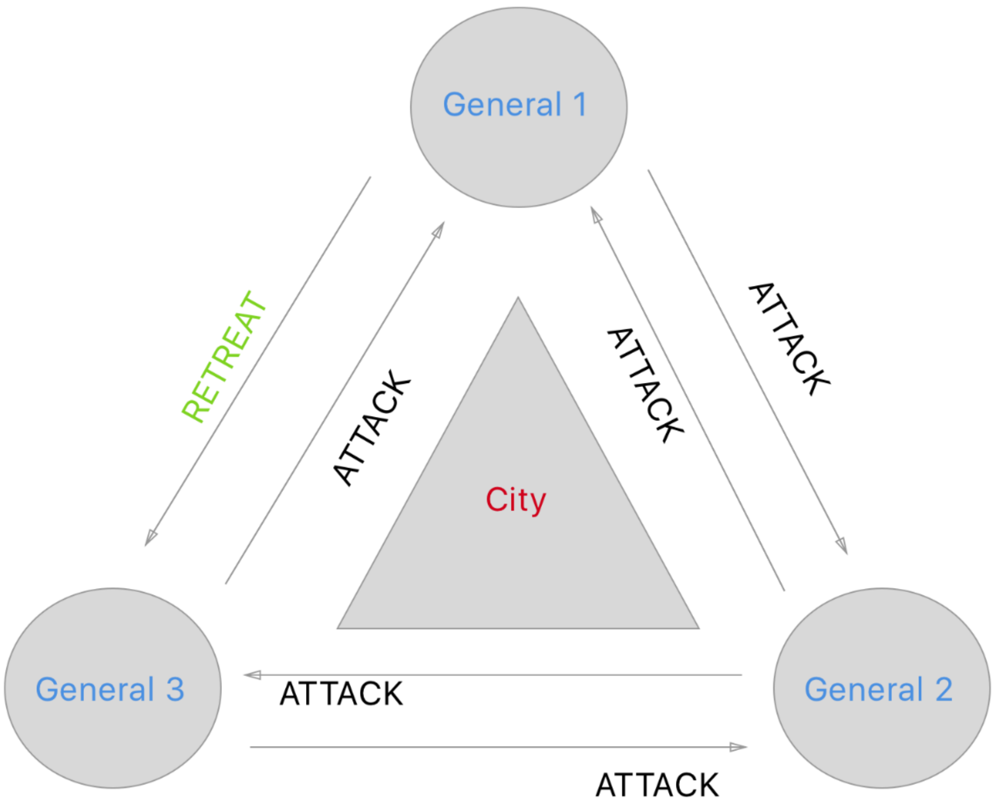


Figure 4The byzantine Generals Problem

Blockchain has to reach a distributed consensus also in a situation like the one described above. It should be “Byzantine fault tolerant”. In order to resolve this problem several algorithms have been developed, the key ones are: Proof of Work (PoW) and Proof of Stake (PoS). We are going to explore them in the following pages, but before, in order to understand those two different protocol, we have to explain what the concept of “mining” is.

2.7.2 Mining

Although many associate mining with bitcoins (which in fact used it first), this, is a general concept.

Particularly, mining is the procedure that consents transactions to be validated, gathered into blocks and added to the Blockchain.

The nodes that take part in this process are known as miners. More specifically, a miner is responsible for:

- Verify that the transactions are valid - for example, in the case of crypto-currency transactions, that the amount to be transferred is existing - and if so, propagate them to the rest of the network.
- Check, together with the nodes, that the new blocks are valid, and if so, propagate them to the network
- Choose transactions, sort them and aggregate them into a block

A full node, on the other hand, is responsible for

- Verify that the transactions are valid and propagate them to the rest of the network.
- Verify that the new blocks are valid and propagate them to the rest of the network.

A full node, therefore, contributes to the security of the blockchain by checking the validity of each transaction and each block, so to ensure that the miners do not cheat: if a miner creates an invalid block, in fact, the other nodes will reject it.

When the block of a miner is added to the Blockchain, it is rewarded for the work done according to the rules of the Blockchain in question. In the case of bitcoints, the reward consists of the cryptocurrencies themselves: at first 50 bitcoin, today 12,5[15].

2.7.3 Proof of Work (PoW)

The proof of work is a protocol used in the process is to reach distributed consensus. Concretely, it is based on the search of a number that is computationally difficult to find, but once found it becomes easy for all other nodes to verify its correctness. In a system that uses the PoW, a block is valid only if it contains a valid solution.

In PoW mining the network nodes compete to solve a complex mathematical problem. The first miner who solves the problem has the right to create the next block and gain the reward. Once the new block is created, it is transmitted to the network, waiting for other nodes to check its validity. It is very easy for the remaining nodes to check if the solution is correct. If the block is valid, it is forwarded to the other nodes, otherwise it is ignored. Pow is therefore a protocol used to reach distributed consensus in which the voting power is based on computational power.

Mining, in a PoW based system, can be summarized in the following points:

[15] https://www.bitcoinblockhalf.com/

1. Transactions are created and transmitted to the entire network of nodes.

2. Each miner chooses the transactions he wants (usually those with the highest commissions) and collects them in a block, that, however, is still not valid.

3. Each miner starts to perform calculations to find the solution to the mathematical problem and generate a valid PoW for the block he assembled.

4. When a miner generates a valid PoW for the new block, the transmits the block to the network.

5. All the network nodes check whether the new block is valid or not.

6. If the block is considered valid, the miner wins the block. The new block is forwarded to the network of nodes and added to the blockchain.

2.7.3 Hash rate

Previously we talked about computing power, this, in the PoW, is calculated as the number of hashes calculated per second (H/s). The hash rate of the network is the sum of all miners’ hash rates. Therefore, a miner's probability to be the first of finding a valid PoW is: network hash rate/ miner hash rate.

Understanding this concept is essential because it helps us understand the vulnerably of the PoW protocol.

In facts, if a miner would reach 51% of the total computing power of the network, it would (theoretically) be able to create blocks faster than all the remaining miners together. The minier in question could reverse or modify some of its transactions, the so-called double spending, or block the confirmation of new transactions, the so-called censorship of transactions. However, a miner can never create a transaction for someone else because. In order to do that they would need the digital signature of that person, the so-called their private key. Sending Bitcoin from someone else’s account is therefore (almost) impossible.

Furthermore, we must also say that an attack of this kind is unlikely to happen in Blockchains with a high total hash rate like Bitcoin. First, because it would require the use of an incredible amount of resources and, secondly, because if someone managed to put together more than 51% of the computing power would be much more profitable for him to follow the rules of the blockchain.

2.7.4 Proof of Stake (PoS)

The Proof of Stake (PoS) is another kind of protocol used to reach the consensus. Unlike PoW, in which the miners rewarded are the ones that are able to solve mathematical problems, with PoS the creator of the next block is chosen in advance via various combination of different parameters, depending of the typo of algorithm used. The validators (the creators of the next block) are chosen, usually, based on the amount of cryptocurrency in their possession for the relevant blockchain, but there may be other parameters such as, for example, the time the validator was in possession of those tokens.

Compared to PoW, PoS is more efficient, because it does not require complex computational calculations for the creation of each new block[16]. (Bentov, et al., 2014).

In addition, attacks, according to many, are more expensive:

1) Although theoretically more likely, buying 51% of tokens would be very expensive. In facts, if an attacker tries to buy 51% of the tokens, the market would react with a rapid and vertical increase in prices, making very difficult to reach the 51% threshold.

2) People with many tokens have less incentive to attack the blockchain, in fact an attack would result in a devastation of confidence in that blockchain, and therefore the value of those tokens.

2.8 51% Attack

It should be borne in mind that, in the PoW, if a miner reached 51% of the total computing power of the network, it would be able to create blocks faster than all the remaining miners together. It may then be able to reverse or modify some of its

[16] Bentov, I., Lee, C., Mizrahi, A., & Rosenfeld, M. (2014). Proof of Activity: Extending Bitcoin's Proof of Work via Proof of Stake. IACR Cryptology ePrint Archive, 2014, 452.

transactions (double spending) or block the confirmation of new transactions (transaction censorship).

However, if a miner were to succeed in carrying out a 51% attack, he would still not be able to modify the old transactions, as he would have to recalculate the PoW of all subsequent blocks while the other honest miners continue to undermine on the correct blockchain. Even in the PoS a 51% attack is possible but, in this case, the attacker will not need 51% of the total hash rate but 51% of the total tokens.

2.9 Cryptography and Addresses

Cryptography occupies a particularly important place in blockchains.

Cryptography is the study of secure communication in a hostile environment and it has been used to create and secure transactions, which must be authenticated by digital signatures, and to generate addresses.

2.9.1 Addresses

Addresses identify the destination of a transaction and can be shared without any security problem as they are generated by encryption in the following way:

1) A private key is generated. This is represented by a random number and must remain secret.

2) From the private key is derived a corresponding public key through a mathematical process. This, unlike the private one, can be shared with anyone.

Generating a public key from a private one is computationally very easy, but reversing the operation is virtually impossible.

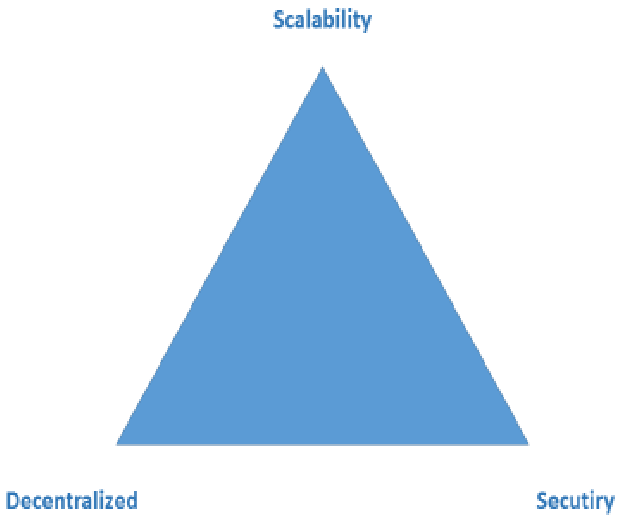
3) The public key is passed through a series of cryptographic algorithms to get an address on the blockchain.

It is important to remember, however, that the blockchain is a list of transactions, the coins are only accounting items and the final balance of an address is a calculation made by examining all transactions involving that address.

Owning the private keys of that address means owning (for example) the bitcoins connected to it.

3. Blockchain Trilemma

The concept ok Blockchain Trilemma, originally introduced by Vitalik Buterin, the founder of Ethereum (ETH), states that it is not possible to maximize all three properties of scalability, security and decentralization at the same time but only two of them at the expense of a third[17]. (Abadi, Brunnermeier, 2018)



Blockchain Trilemma

The trilemma is based on the fact that, if for example there are a large number of nodes, the network will be secure and decentralized, but this will be at the expense of its scalability. In fact, all nodes must validate transactions and the more nodes there are, the longer it will take to validate a transaction.

[17] Abadi, J., & Brunnermeier, M. (2018). Blockchain economics (No. w25407). National Bureau of Economic Research.

Conversely, as in the case of Hyperledger (a private blockchain), if to participate in the network, you expect permission from a central authority, you can reach high levels of transactions per second and at the same time remain immune from manipulation. Such a configured blockchain, however, cannot be considered as actually decentralized.

3.1 Lightning Network

The way to solve this trilemma was found in the Lightning Network, a technology that allows an exponentially higher number of exchanges in the network without weighing down the blockchain, since these exchanges take place on a second "layer", or "layer" off-chain. (Poon, Dryja, 2016)[18]

At this point, it is important to draw the first conclusions and explain what goals can be achieve by this extraordinary technology.

[18] Poon, J., & Dryja, T. (2016). The bitcoin lightning network: Scalable off-chain instant payments.

4. Smart Contracts

The concept of smart contract was introduced, for the first time, by Nick Szabo during the 1994. He defined it as “a computerized transaction protocol that executes the terms of a contract”[19] (Szabo, 1994)

The idea behind a Smart Contract is to translate contractual clauses into code, making it self-executing and self-enforcing, in a way that the need for trusted intermediaries between transacting parties would be minimized, as well as the occurrence of malicious or accidental exceptions[20]. (Christidis, Devetsikiotis, 2016). Thanks to the blockchain technology the concept that Szabo suggested 20 years ago became not only feasible, but also popular.

When we speak about smart contracts within the blockchain context, in facts, we mean a generic program that has all the characteristics of a contract but that it is saved and executed within a blockchain.

Smart contracts, since are written in a programming language on a blockchain, are unambiguous. There is no need for an external authority to evaluate the terms of the contract and to take decisions because this task is entrusted to the consensus within the network. Replacing lawyers and banks that have been involved in contracts for asset deals depending on predefined aspects[21]. (Fairfield, 2014)

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[19] Szabo, N. (1994). Smart contracts, 1994. Virtual School.

[20] Christidis, K., & Devetsikiotis, M. (2016). Blockchains and smart contracts for the internet of things. Ieee Access, 4, 2292-2303.

[21] Fairfield, J. A. (2014). Smart contracts, Bitcoin bots, and consumer protection. Wash. & Lee L. Rev. Online, 71, 51.

In the Italian legislation, the Law 11 February 2019 n. 12, Art. 8 ter, Technologies based on distributed registers and smart contract:

> *"A smart contract is defined as a computer program that operates on technologies based on distributed registers and whose execution automatically binds two or more parts on the basis of effects predefined by the same"*

And,

> "*Smart contracts meet the requirement of written form, after computer identification of the parties concerned, through a process that meets the requirements set by the AgID with guidelines ...".*

4.1 Decentralized Autonomous Organization (DAO)

Every Smart Contract is, actually, an IFTTT (If This Then That) code, meaning that when certain predetermined terms are met the contract executes automatically.[22] (Nordgren, et al.)

Despite the growing trust on smart contracts, their actual trustworthiness and security has still to be assessed. An unsafe design choice for the programming

[22] Nordgren, a., weckström, e., martikainen, m., & mlehner, o. T. H. M. A. R. Blockchain in the fields of finance and accounting: a disruptive technology or an overhyped phenomenon?. Journal of finance & risk perspectives issn 2305-7394, 47

languages for smart contracts can be fatal, as witnessed by the unfortunate epilogue of the DAO contract[23], a crowdfunding service plundered of about 50M USD because of a programming error. Since then, many other vulnerabilities in smart contract have been reported.[24] (Bartoletti, Pompianu, 2017)

Dao was a (smart) contract with tens of thousands of participants launched on April 30, 2016, which dealt with raising funds to establish a Decentralized Autonomous Organization.

Although the contract was apparently well written and the Ethereum network considered safe, in June 17, 2016 a group of users, taking advantage of a computer "bug" located in the contract and dependent on the fact that some instructions of a single function were not in the correct order of execution, managed to steal the funds of the contract.

After the theft, the Ethereum community was faced with a choice: lose all the funds on the contract or change the history of the blockchain, going against the principle of immutability.

The second option was chosen, making a Hard Fork with which the "incriminated" contract and its transactions were artificially eliminated.

The knots that did not accept the fork (20%), gave rise to an alternative version of Ethereum, called Ethereum Classic.

[23] Understanding the DAO attack, http://www.coindesk.com/understanding-dao-hack-journalists/.

[24] Bartoletti, M., & Pompianu, L. (2017, April). An empirical analysis of smart contracts: platforms, applications, and design patterns. In International conference on financial cryptography and data security (pp. 494-509). Springer, Cham.

These events must be a warning to programmers in the industry: encode a smart contract on a blockchain produces an immutable program that cannot be modified, so it is very important to test it thoroughly and take every care in its creation.

4.2 Oracles

What happens if some contractual actions should depend on details about the past, present or future? For example, automate a refund if your flight is delayed tomorrow?

This is where the so-called oracles enter the equation. Intelligent contracts require oracles to resolve details, which cannot be known precisely at the time of drafting the contract.

Truth is subjective, subjectivity is delegated to oracles: but how do we resolve subjective events in a demonstrable, consistent, transparent and minimally reliable way?

In itself, the blockchain cannot access data outside the network: for this purpose, the oracles intervene, third-party agents that stand between the blockchain (and therefore the smart contracts) and the real world, with the aim of passing information to Smart Contracts as soon as some external condition occurs. They then provide the blockchain with external data and "trigger" the execution of smart contracts as soon as a certain condition is met, a condition that requires information not known at the time of writing the contract.

Unfortunately, no way has yet been found to ensure that the oracles give 100% correct information or that it is not forged. For this reason, trust in the oracle plays a very important role in smart contracts.

5. More Efficient Markets

In the previous chapter we analyzed how the blockchain technologies work. From what we said, it is easy understandable that the power of this new technology is "*allowing any two willing parties to transact directly with each other without the need for a trusted third party."* (Nakamoto, 2008).

Thanks to its rules specifically intended to incentivize the spread of new, legitimate transactions; reconcile conflicting information and reach consensus about the true state of the ledger in an environment where not all contributing nodes can be trusted (e.g. as during a malicious attack to the network), Bitcoin was the first example, of costless verification[25]. (Catalini, Gans, 2016)

In this master thesis we support the argument, heavily supported by the literature, that low costs, fast processes and flexibility can be reached using the blockchain technology.

The Blockchain technology, in fact:

> "*changes the way we transact, with the underlying transaction model shifting away from a centralised structure (banks, exchanges, trading platforms, energy companies) towards a decentralised system (end customers, energy consumers). Third party intermediaries, whose services are needed today in most industries, are no longer required in such systems – at least according*

[25] Catalini, C., & Gans, J. S. (2016). Some simple economics of the blockchain (No. w22952). National Bureau of Economic Research.

> *to the blockchain theory – given that transactions can be initiated and carried out directly “from peer to peer”. This can cut costs and speed up processes. As a result, the entire system becomes more flexible, as many previously manual work tasks are now carried out automatically through smart contracts*.” (PriceWaterhouseCooper, Blockchain: Opportunity for Energy Producers and Consumers)

The first key of the blockchain success, and, as to the purpose of this work, of their validity as enabling technology for energy communities, is that the blockchain technologies represent the important promise of making markets more efficient.

However, this promise has its limits. In facts, as we are going to see as follow, the main grounding to which this promise uphold has its own limits too.

6. Trust and Its Limits

The 2008 white paper that first proposed bitcoin, written by the anonymous Satoshi Nakamoto, reads: *"I've developed a new open source P2P e-cash system called Bitcoin. It is completely decentralized, with no central server or trusted parties, because everything is based on crypto proof instead of trust*" and ends with the phrase "*We have proposed a system for electronic transactions without relying on trust*". (Nakamoto, 2008)

In facts, the concepts that we are going to summarize in the following lines are some of the basic concepts of the blockchain technology as well as, in our opinion, the drivers of trust. Those are:

1. Decentralization
2. Transparency
3. Safety and security
4. Immutability
5. Consent

However, even if with the blockchain technologies there is no need to trust any institution or any actor involved, we still have to trust the system.

Trust, in the blockchain technology, is guaranteed through a clever mixture of cryptography and incentives, that allows any contributor in the network to query and verify the state of a specific transaction in the digital currency. However, it is impossible for the system to be 100% secure. For example, in January 2019, someone took control of the computer force of Ethereum Classic (Etc) and used it to rewrite the history of transactions, thus being able to spend the same currency twice. It used 88,500 tokens twice, equivalent to 500,000 dollars[26]. (Brandom, 2019)

One of the main problems that we are aware of is the condition that can be determined if more than half of the nodes of a blockchain agree to modify the contents of a transaction. In such a case, without anyone noticing it, the reliability of the chain could be compromised. It is interesting to note that in the case of bitcoin more than half of the hash rate is concentrated in 5 mining pools and more than 70% of the hash rate is concentrated in China. (www.blockchain.com/pools)

Another big issue with blockchain is that the more numerous the number of nodes are, the more secure the system is, but it greatly increases the number of nodes that "compete" for the closure of the block of transactions. Obviously, this is very true in the case of cryptocurrencies, where you receive a fee for this activity, but it is also true in the case in which nodes validate transactions based on alternative rules. In this case, to preserve the security and reliability of the system, it is important that the rules for closing the blocks are such that it is impossible to determine in advance which node is involved or it would be vulnerable to attacks.

Moreover, we also need to trust developers and smart contracts. In the case of developers, even if the code is very often open source, only a small percentage of users have the skills and time to understand and analyse this code. We must trust

[26] https://www.theverge.com/2019/1/9/18174407/ethereum-classic-hack-51-percent-attack-double-spend-crypto

developers to write good software. For the case of smart contracts, that, as we will see below, are applications that run within a blocklchain, they could contain vulnerabilities. Some smart contracts in facts have been attacked after collecting millions of dollars (for example the DAO was hacked after collecting 150 million dollars)[27]. (Siegel, 2016)

[27] Siegel, D. (2016). Understanding the dao attack. Retrieved June, 13, 2018.

7. Data Storage

Another key argument to which we, and the literature, base the understanding of the blockchain technologies as enabler of innovation is their data storage capacity.

Cloud storage firms frequently store client data on a centralized server. This increases the network’s vulnerability against hacker’s attacks. Cloud storage based on Distributed ledgers, instead, enable decentralized storage and thus reduce the system's exposure to attacks[28]. (Zyskind, Nathan, 2015)

There are several advantages to use storage from a blockchain-based storage network.

1) Distributed storage over a blockchain is cheaper than traditional cloud-based storage. Enterprises using blockchain for storage do not have to buy and maintain equipment or software.
2) Blockchain data storage delivers more transparency than a traditional cloud service. With data distributed across multiple nodes, blockchain technology is able to provide higher levels of availability and fault tolerance. Blockchain also offers performance advantages because users can access data closer to where it is stored.

[28] Zyskind, G., & Nathan, O. (2015, May). Decentralizing privacy: Using blockchain to protect personal data. In 2015 IEEE Security and Privacy Workshops (pp. 180-184). IEEE.

3) Blockchain storage is also thought to be more secure than centralized storage because the data is spread out across many data points. Distributed storage is less likely to be universally hit by invasive malware.

In order to understand how blockchain backed data storage services may have an impact take into account that the global internet traffic has tripled since 2015, and is expected to further double by 2022 to 4.2 zettabytes per year (4.2 trillion gigabytes)[29] (Cisco, 2015; 2018; 2019).

The number of mobile internet users is expected to increase from 3.6 billion in 2018 to 5 billion by 2025, while the number of Internet of Things (IoT) connections is expected to triple from 7.5 billion in 2018 to over 25 billion by 2025[30] (GSM Association, 2019).

These trends are driving exponential growth in demand for data centre and network services.

In regards of the energy sector, with a focus on electricity, the global data centre electricity demand in 2018 was an estimated 198 TWh, or almost 1% of global final demand for electricity (Masanet et al., 2018).

[29] Cisco, C. (2015). Cisco 2015 annual security report.
[30] GSM Association, (2019), The Mobile Economy 2019 - GSMA Intelligence.

II. BLOCKCHAIN AS GENERAL-PURPOSE TECHNOLOGY

To our understanding the blockchain technologies can be labelled as enabling technologies, especially for the spread of energy communities. This is the scope of this work indeed. However, the literature has its own way to label technologies and their projectable importance in the economy and in the everyday life as well.

This label is known as General Purpose Technology (GPTs). In the following chapter we will analyse what it means, which are its characteristics, and finally we will question ourselves whether the blokchain technologies may be labelled as such.

Recall that the concept of general-purpose technology is not a mathematical calculation and, as such, it is subject to interpretations. Moreover, this concept, even when backed by data, has the scope to understand the potential of a technology in future scenarios. Hence, the qualification of being a general-purpose technology, for a technology at its early stages as the blockchain one, provides little information. Nevertheless, it is worth to dig deeper into this concept.

1.1 What GPTs are

General-purpose technologies, further referred as GPT, are technologies that can affect an entire economy (usually at a national or global level).[31] [32] (Bresnahan, Trajtenberg, 1995).

GPTs have the potential to drastically alter societies through their impact on pre-existing economic and social structures. Examples include the steam engine, railroad, electricity, electronics, material handling, mechanization, control theory (automation), the automobile, the computer and the Internet.[33] (Landes, 2003)

Bresnahan and Trajtenberg classify GPTs as "*enabling technologies*", technologies that enable new sets of opportunities alternatively to offering complete solutions. Helpman & Trajtenberg gave a similar definition: they define GPTs as "*engines of growth*".

More precisely, we can say that a "*General Purpose Technology* has to be a new technology with *substantial* and *pervasive* impact across the whole of society (Youtie, Iacopette, & Graham, 2007).

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[31] Rosenberg, N., & Nathan, R. (1982). Inside the black box: technology and economics. cambridge university press.

[32] Bresnahan, T. F., & Trajtenberg, M. (1995). General purpose technologies 'Engines of growth'?. Journal of econometrics, 65(1), 83-108.

[33] Landes, D. S. (2003). The unbound Prometheus: technological change and industrial development in Western Europe from 1750 to the present. Cambridge University Press.

1.2 How to Identify a GPT

In this section we are interested in understanding whether the Blockchain technologies can be labelled as GPTs. In order to do so we must look more closely at the literature about GPTs.

In facts, the literature describes some features that must be met in order to assess whether a technology can be regarded as a GPT.

According to Bresnahan and Trajtenberg (1996) a *General-Purpose Technology*, (GPT), should have the following characteristic:

The first one, as in Youtie, Iacopette, & Graham, is *pervasiveness*: the ability of the GPT to spread to most sectors, an example could be electricity that is utilised from heating and lighting our houses to powering trains. A pervasive technology is a technology, which is use in huge number of products through an economy and in several applications.[34] (Korzinov, Savin, 2016).

The second characteristics that a GPT should have is known as *improvement* and it is the capability of the technology of lowering the costs of its users, as more people are using it. Putting it in another way, these technologies, in order to be considered GPTs, should experience significant improvement in their efficiency and effectiveness throughout their lifetime. (Korzinov, Savin, 2016).

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[34] Korzinov, V., & Savin, I. (2016). Pervasive enough? General purpose technologies as an emergent property (No. 95). KIT Working Paper Series in Economics.

This feature is also known as *technological dynamism*. (Bresnahan, Trajtenberg, 1995)

Finally, the GPT should be spurring innovation both in products, services or processes. This last feature is known as *innovation spawning*.

1.3 Why GPT's Are Important

In this chapter, we are presenting some literature about the GPTs in order to assess whether the Blockchain technologies may be regarded as one of them. This is not a futile exercise, in facts, we see three main reasons for doing that:

(1) Spur an effective government innovation policy

(2) Understanding the technological drivers of economic growth

(3) Predicting the way in which we could most effectively prepare for these broad technological changes[35].

(Youtie, Iacopetta, Graham, 2008).

1.3.1 R&D Policy

[35] Youtie, J., Iacopetta, M., & Graham, S. (2008). Assessing the nature of nanotechnology: can we uncover an emerging general purpose technology?. The Journal of Technology Transfer, 33(3), 315-329.

It is commonly believed that measures aimed at making intellectual property rights stronger, or inventors' appropriability of the social surplus generated by inventions greater, tend to increase the supply of innovation, without regard to missed opportunities for diffusion.

Hence, being able to assess whether a technology is a GPTs, with all its potentials and its benefits for society, may help in deciding the best way of spurring that technology.

Therefore, if a technology is a GPT it may be more efficient to resolve the classical tension between creating monetary incentives for innovators and fostering the diffusion of innovation by opting for a relatively high level of externalities. (Youtie, at al., 2008)

1.3.2 Economic Change

Another reason for assessing whether a technology is a GPT or not is that such analysis provides insight into the source of economic expansions or slowdowns.

As advocated by Helpman and Trajtenberg (1994)[36], when studying economic growth, the entrance of a GPT seems to be followed by a first stage of stagnation, or even the decline, of wage and labour productivity rates. This apparently negative

[36] Helpman, E., & Trajtenberg, M. (1994). A time to sow and a time to reap: Growth based on general purpose technologies (No. w4854). National Bureau of Economic Research.

outcome is due to the diversion of resources from existing production activity to the creation of new technologies complementary to the GPT.

This stage is frequently mentioned as ''*time to sow*''. The economy in facts appears unproductive in the short run either because the technology used are not yet efficient or because adopters do not possess the required skills and knowledge to use them efficiently.

It has been argued that the productivity slowdown that lasted for almost 25 years, from the first half of the 1970s was partly due to the spread of computers.(Youtie, Iacopetta, Graham, 2008)

1.3.3 Societal Synchronization

Lastly, assessing whether a technology can be labelled as GPT is important also for its own development. As we know, developments in the GPT needs R&D investments. Those will likely be made only if the investors expect the expansion of new complementary technologies or the refinement of existing technology in downstream sectors. In turn, complementary technologies will emerge only if inventors are optimistic about the prospect that the GPT will be widely adopted. . (Youtie, Iacopetta, Graham, 2008)

1.4 Is Blockchain a GPTs?

As we showed above, a GPT should have some characteristics: the scope for improvement, the wide range of use and the likelihood of spawning complementary innovations. In this section we will look at each of these features, trying to describe whether and how the Blockchain technologies comply with them.

1.4.1 Wide Range of Use

It is easy understandable how a transparent, verifiable and decentralized register of transaction data that is also resistant to fraud, may have endless applications. For this reason, in the later years many scholars wrote about the various direction that the Blockchain technologies could take. In facts, even if Blockchain has been used mostly to create crypto-currencies and just lately is starting to be used for smart contracts, many agrees in the fact that Blockchain technologies will extends to other segments of the economy (Swan, 2015).

Always according to Swan *all modes of human activity could be coordinated with Blockchain technology to some degree, or at a minimum reinvented with Blockchain concepts."* (Swan, 2015, p. 37), he also presents the Blockchain technologes as the "*next major disruptive technology and wordwide computing paradigm*".

The same forecast has been done by many other scholars, according to Tapscott & Tapscott (2016) the following twelve areas are likely to adopt Blockchain with a disruptive effect. These twelve areas are:

i.) Transportation

ii.) Infrastructure management

iii.) Energy, waste and water management

iv.) Resource extraction and farming

v.) Environmental monitoring and emergency services

vi.) Health care

vii.) Financial services and insurance

viii.) Document and other record keeping

ix.) Industrial operations

x.) Home management

xi.) Retail operations

xii.) Sales.

1.4.2 Scope for Improvements

The scope for improvement is the ability of the technology of lowering the costs of its users, as more people are using it. In another way, the ability of the technology of experiencing significant improvement in its efficiency and effectiveness throughout its lifetime. (Korzinov, Savin, 2016)

Hence, the question that we should ask ourselves is whether the Blockchain technologies were able to increase their efficiency and effectiveness in the last years. (Korzinov, Savin, 2016)

Using bitcoin as a proxy of the development of the Blockchain as it is its most developed application, we can look at the different cryptocurrencies born after the introduction of Blockchain. We can already see a great improvement in the technology's efficiency and effectiveness: in facts, if Bitcoin can only handle seven transactions per second, Ethereum can handle 15 to 20 transactions per second, Lightcoin 56 transactions per second and Ripple 1500 transactions per second.

Moreover, Bitcoin code itself was improved several times: when initially designed, the code was made public for developers to continuously improve it. These improvements of the Bitcoin code are made though a *Bitcoin Improvement Proposal* with which developers propose new features or improvements to the community. Hence, appears clear how as more people are using it and as the community becomes larger the Bitcoin code would increase its efficiency. The very same process can be imagined for all the Blockchain technologies.

1.5 Conclusion

At this point seems reasonable to assess that Blockchain technology can be labelled as an "*enabling technology*". However, even if Blockchain characteristics follow perfectly the ones of a GPT, they still are in their early stage. If one or more of the criteria will fail to develop, Blockchain will fall into the category of failed GPTs. As Allen states we cannot yet define Blockchain as a GPT, nevertheless it can be defined as a "*Potential General-Purpose Technology*". (Allen, 2016)

III. THE ENERGY SECTOR

1. Introduction

As we said before the main improvements of the blockchain technologies, beside the creation of trust in untrusted environments without a central authority, that spurs decentralization - even if we already shown the limits of this trust - are, lower costs, faster processes and greater flexibility.

Those features offer a great potential for innovation, especially in the service sector. Among all the different subsectors, the one that was hyped the most is for sure the financial one. In facts, the banking industry and the financial sector in general have spent more than 550 million dollars on blockchain in 2018 and it is projected that the spending will keep increasing by 75% every year for the foreseeable future[37].

For the most part this phenomenon can be explained by the fact that, in the financial sector, the blockchain transaction model can deliver enormous cost cutbacks and make processes more efficient, all within a small amount of time.

Meanwhile lots of companies already rose up around Bitcoin and lots of major banks and start-up companies are using other financial uses of blockchain since

[37] https://www.tradingpeek.com/

years, other industries are only just starting to use the blockchain technologies in their business.

Some of the most interesting cases concerns the use of blockchain technologies in the energy sector. Here, as in the case of financial use, we find not only start-ups, spin-offs and small projects, but also some that are heavily funded by large energy companies. Also for this reason, among all the others that will emerge during this Master Thesis - like the environmental benefits that such projects could deliver - we think that the blockchain technologies in the energy sector have – and will have – a particular relevance, and that it is worth to study and explore. Particularly, the main usage of blockchain within the energy sector can be found, in our opinion, in renewable energy communities, communities of energy users in which energy is traded between peers.

Even if these communities, as we aim to demonstrate, can be enabled by technological advancements such as the blockchain, the debate on energy innovation has long gone beyond the scope of issues relating to the technological progress of energy systems.

Energy innovation, in fact, increasingly concerns the organizational model, understood as innovation in the organization and ownership of energy production plants, and in the progressive involvement of local communities in decision-making processes[38]. (Patrucco, 2018)

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[38] Patrucco, D., Transizione energetica, i fattori umani e sociali non possono essere trascurati, QualEnergia.it, 12/11/2018.

For these reasons we are going to introduce, describe and comment the European regulatory framework and the Italian one as well, pinpointing its points of strengths and its deficits as well.

In any case, issues concerning the self-production and local distribution of energy from renewable sources have acquired a certain importance in public opinion[39], (Bollino, 2009) also thanks to the opportunities that are opening up thanks to the reduction of the costs of technologies, the evolution of networks, the improvement of efficiency and, more generally, the innovation of energy governance.

Financial innovation mechanisms also support the active participation of consumers and local communities in the energy system. Among the alternative sources of financing, which have experienced substantial growth on the global scene in recent years, crowdfunding is particularly suited to local development initiatives, and the blockchain technologies may have a positive impact to its development, increasing their weight in their overall importance for the development of energy communities. The mechanism of Initial Coin Offerings (ICOs) assumes a relevant importance in the fund sourcing of *bottom-up* initiatives as well. For the discussion of this topic, please refer to the chapter *"ICOs And Crowdfunding".*

International European policies and commitments made through intergovernmental agreements have been pushing in the direction of reducing climate-changing gas emissions, adopting energy efficiency measures and, particularly, increasingly

[39] Bollino, C. A. (2009). The Willingness to Pay for Renewable Energy Sources: The Case of Italy with Socio-demographic Determinants. Energy Journal, 30(2).

generating energy from renewable sources[40]. Concerns about the security of energy supply and, more generally, about independence of supply also have an impact on the willingness to support the transition of the European Union's energy system towards a low-carbon structure[41]. While this impressive transition process, which has been going on for several decades, is led by states, major investors and the most important companies in industry and transport, smaller players, local communities and individual consumers can also play an important role in promoting renewable energy, revising production and consumption patterns and supporting investment in clean energy[42]. (Van Der Schoor, Scholtens, 2015).

In fact, the progressive liberalization of the markets combined with the development of decentralized energy systems, stimulated by the growth of renewables, has opened spaces for action so that traditional users of the energy system can become prosumers or co-producers of energy services. Therefore, the participation of consumers in the sustainable transition is increasingly in the attention of legislators and consumers have now begun to develop and manage energy projects according to different ownership structures than those of traditional companies.

This is the case for energy communities.

[40] REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL EU and the Paris Climate Agreement: Taking stock of progress at Katowice COP (required under Article 21 of Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC) COM/2018/716 final.

[41] Union, I. (2014). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. A new skills agenda for europe. Brussels.

[42] Van Der Schoor, T., & Scholtens, B. (2015). Power to the people: Local community initiatives and the transition to sustainable energy. Renewable and sustainable energy reviews, 43, 666-675.

1.2 Utilities

The utilities sector refers to a category of companies that provide basic facilities, such as water, sewage services, electricity, dams, and natural gas. (Murphy, 2019)

Those companies, called public utility companies, or usually just utility, are organizations that maintain the infrastructure for a public service and often provide a service using that infrastructure too. Broadband internet services (both fixed-line and mobile) are increasingly being included within the definition.

Public utilities are subject to forms of public control and regulation ranging from local community-based groups to state-wide government monopolies[43]. (Groenewegen, de Vries, 2016).

Here we will focus particularly on the energy sector.

The energy sector has a huge importance for our economic development since affordable energy facilitates economic growth[44]. Nevertheless, our scope is not to show this link, neither is to enumerate simply the several ways in which the blockchain technology may facilitate – for example reducing costs – the work of large companies in the sector. Conversely, our aim is to present the blockchain technologies as an engine for innovation, able to disrupt the utilities sector as we know it today. In facts, today, energy-producing homeowners can only provide their

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[43] Groenewegen, J., & de Vries, P. (2016). Coase and the regulation of public utilities. In The Elgar Companion to Ronald H. Coase. Edward Elgar Publishing.
[44] Yergin, D., & Gross, S. (2012). Energy for Economic Growth: Energy Vision Update 2012; Industry Agenda. World Economic Forum.

renewable energy to the public utility. Instead they cannot sell their renewable energy to other homeowners.

The main motive why they cannot sell to each other is that states have granted a legal monopoly over supplying energy[45]. (Summers, 2019)

The reason behind that behavior is that the energy industry is generally considered a natural monopoly, meaning that the large need for infrastructure and capital make almost impossible for anyone to enter the market, and, most importantly, to adequately supply energy to consumers[46].

As we aim to present, this is not automatically true today, thanks to the progresses of new technologies such as the blockchain. Nevertheless, such technological advancements must be backed by improvements in the legislative framework as well.

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[45] Adam B. Summers, End monopoly protections to fix PG&E and other utilities, The Orange County Register, https://www.ocregister.com/2019/03/16/end-monopoly-protections-to-fix-pge-and-other-utilities/, Mar. 16, 2019.

[46] Steve Corneli and Steve Kihm, Will distributed energy end the utility natural monopoly?, Electric Policy, https://emp.lbl.gov/sites/all/files/Corneli_29June2016.pdf, Jun. 29, 2016

9.3 The structure of the energy system and generation from renewable sources.

Renewable energy sources (RES) have experienced massive developments throughout the last years, permitted by privatisation, unbundling of the energy sector and improved by financial incentives and energy policy initiatives.

In 2016, 24.6% of the UK gross electricity consumption was produced by RES, mainly from onshore and offshore wind farms and PV solar plants, accounting for 44.9% and 12.5% of the total 35.7GW installed RES capacity, respectively[47]. (BEIS, 2017)

At the European level, the share of energy from renewable sources in gross final consumption of energy was 17% in 2016, the double of the share in 2004, that was 8.5%.[48] The Europe 2020 strategy includes a target of reaching 20% of gross final energy consumption from renewable sources by 2020, and at least 27% by 2030.

The share of renewable sources in gross final consumption of energy has grown in all member state since 2004. The leading state was Sweden with over half (53.8%) of its energy provided by renewable sources in 2016 in terms of gross final energy consumption, followed by Finland (38.7%), Latvia (37.2%), Austria (33.5%) and Denmark (32.2%). The lowest proportion of renewables in 2016 was recorded in Luxembourg (5.4%) followed by Malta and the Netherlands (6.0% each).

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[47] Department for Business. Energy & Industrial Strategy (BEIS), DIGEST of United Kingdom energy statistics 2017 Chapter 6 Renewable sources of energy, ⟨https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/643414/DUKES_2017.pdf⟩, [accessed 5 Jun 2018] (2017).

[48] Share of renewables in energy consumption in the EU reached 17% in 2016. Eurostat News Release, 25 January 2018.

Italy too, as far as renewable sources are concerned, has a positive situation with respect to the EU 20-20-20 objectives. Total gross final consumption of energy from renewable energy sources reaches 21.8 Mtoe (million tonnes of oil equivalent) by 2017, based on a preliminary estimate of 123 Mtoe of total gross final consumption. Therefore, the incidence of renewable energy sources is 17.7% (GSE - Gestore Servizi Energetici s.p.a., data updated to 2017).

Italy, moreover, has an important base of renewable generation. It has, in facts, a robust structure of small-medium size plants spread all over its area. In the 2013 there were 515 thousand plants installed, of which almost 500 thousand were small photovoltaic plants, for a total gross efficient power of 23 GW (about 20% of the gross efficient power of the national generation park) and a gross production of 34 TWh (about 12% of the national production of electricity).

This particularity: the robust structure of small-medium size plants spread all over the Italian territory, will be important when discussing about the potential of Italy for energy communities.

2. Renewable Energy Communities

Renewable Energy Communities are communities of users (private, public, or mixed) located in a specific area of reference where end-users, such as citizens, businesses or the public administration, and market players, designers, planners and politicians actively cooperate to develop high levels of "smart" energy supply. (European Regional Development Fund, 2018)[49]

In other words, renewable energy communities are communities in which the actors listed above cooperate in the generation, consumption, distribution, storage and supply of energy from renewable sources using a smart grid. Here, users act both as a producers and consumers and are generally indicated as “prosumer”[50]. (Ritzer, Dean, Jurgenson,. 2012)

Recall that, a usual electrical grid is an interconnected network for delivering electricity from producers to consumers[51]

A smart grid, instead, is an electrical grid, which includes a variety of operation and energy measures including smart meters, smart appliances, renewable energy resources, and energy efficient resources[52].

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[49] https://www.interregeurope.eu/fileadmin/user_upload/plp_uploads/policy_briefs/2018-08-30_Policy_brief_Renewable_Energy_Communities_PB_TO4_final.pdf

[50] Ritzer, G., Dean, P., & Jurgenson, N. (2012). The coming of age of the prosumer. American behavioral scientist, 56(4), 379-398.

[51] Kaplan, S. M., Sissine, F., Abel, A., Wellinghoff, J., Kelly, S., & Hoecker, J. (2009). Smart Grid. Electrical Power Transmission: Background and Policy Issues. The Capital. Net, Government Series, 1-42.

[52] Federal Energy Regulatory Commission. (2008). Assessment of demand response and advanced metering.

However, even if they can be enabled by blockchain technologies, energy communities are not a phenomenon of recent years. The first forms of communities have been developing since the end of the 19th century in various European countries, including Germany and Italy. Similar experiences are repeated later with the production of energy from renewable sources, for example in the 70s in Denmark with the first wind cooperatives, and then in Belgium and Germany, following the Chernobyl accident in 1986. However, it is only since the 2000s that energy communities have been able to present themselves as an important element in the process of transition to a new energy paradigm.

According to the European Union, the renewable energy communities are defined in the text of the recast of the Renewable Energy Directive (RED II)[53], which become into force in the end of 2018.

The text defines renewable energy communities as:

> *A legal entity: i) which, according to applicable national law, is based on open and voluntary participation, is autonomous, and is effectively controlled by shareholders or members that are located in the proximity of the renewable energy projects owned and developed by that community; ii) whose shareholders or members are natural*

[53] European Commission, Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources.

persons, local authorities, including municipalities, or SMEs; iii) whose primary purpose is to provide environmental, economic or social community benefits for its members or the local areas where it operates rather than financial profits.

3. The Legislative Framework

In this section we are going to look at the legislative framework regulating the Renewable Energy Communities.

3.1 The European Union's Energy Policy

Without any doubt, the spreading of renewable energy sources, beside the technological advancements, was also facilitated by the European process of liberalisation of energy markets and by an increasing consciousness of citizens in the circuits of consumption and production. In facts, in order to deal with the enormous amount of CO2 emissions produced by fossil sources the European Union has recently revised its short-term objectives in the areas of renewable energy, energy efficiency, biofuels and energy governance. The new rules, approved by the European Parliament on 13 November 2018 aim to introduce rules aimed at harmonizing European energy governance, to bring renewable energy to cover 32% of the EU's gross energy consumption and to achieve energy savings of 32.5% from energy efficiency.

In order to reach those objectives, the European Union has gone through several policy innovations throughout the years. The "Clean energy for all Europeans" regulatory package, launched by the European Commission in November 2016. There, the European Commission makes explicit reference to "consumers as active and central players in the energy markets of the future […] to whom they can give the opportunity to produce and sell their own electricity "[54] (Clean Energy for All Europeans package, 2018)

On a continental level, self-consumption of energy has been enhanced mainly by the new Renewable Energy Directive (RED II), which is the first legal recognition of self-consumption and energy communities. Specifically, reference should be made to Articles 21 and 22 of the Directive.

On this basis, in relation to self-consumption, Member States will have to take the necessary measures to ensure that self-consumers of renewable energy located in the same building are allowed to organise among themselves the exchange of renewable energy produced at their site (Article 21). This development will enable the production, storage and sale of energy on a one-to-many basis. Furthermore, the Directive prescribes that different subjects can join the so-called "renewable energy communities" based on self-consumption of electricity and on the sharing of the energy produced. Also, in this case, the communities are authorized to use the existing distribution networks, paying the relative charges and following fair criteria based on the specific cost-benefit analysis also at an environmental level (art. 22).

This means that until now, electricity-generating prosumers have not had real access to the energy market, which remains a privileged playing field for the institutionalised energy suppliers. This fact has, so far, heavily impacted on the real

[54] European Commission, "Clean Energy for All Europeans – unlocking Europe's growth potential. EU Commission Energy Winter Package. Novembre 2016.

diffusion at large scale of micro-generation due to the limited economic advantages this energy generation approach would bring to the prosumers. Where with micro-generation we mean the capacity for consumers to produce electrical energy in-house or in a local community[55]. (Ioanni, Raimondo, Dimitrios at al., 2017).

The RED II, has been a real milestone in the history of renewable energies because it would open the way for the creation of real energy communities on the territory.

As we said before, through the new energy governance legislation, Member States are asked to assess existing barriers to self-consumption of energy from renewable sources, in order to ensure that all potential consumers can join the energy communities. In this regard, the legislation regulates possible forms of aggregation (companies, associations, foundations, cooperatives) and support policies (facilitated financing, awareness campaigns on economic and environmental benefits, economic incentives for the inhabitants of the areas concerned, obligation for energy producers to allow the participation of local communities in the ownership of the facilities).

This means that, within a few years, energy communities could revolutionize the energy market. In facts, according to the report *"The Potential for Energy Citizens in the European Union"* – written by the environmental research institute CE Delft on behalf of Greenpeace, European Federation for Renewable Energy (EREF), Friends of the Earth Europe and REScoop.eu- by 2050 half of European citizens,

[55] Ioannis, K., Raimondo, G., Dimitrios, G., Rosanna, D. G., Georgios, K., Gary, S., ... & Igor, N. F. (2017). Blockchain in Energy Communities. A proof of concept.

prosumers and/or energy citizens, could produce, but also manage, their own energy. Moreover, the same report estimates that energy communities could cover 45 percent of total EU demand by 2050.

3.2 The Energy Policy in the Italian Peninsula

However, up to the present time, in Italy the only form of self-consumption allowed is the exchange from a single plant to a single final consumer (one to one), with the remission into the grid of the excess of energy produced. Even if, in the national legislation, we can find a pale recognition of the energy communities, particularly in the National Energy Strategy 2017 (SEN – Strategia Energetica Nazionale), which outlines the development and transition of the Italian energy system through a national plan drawn by the Government.

Despite that, Italy is lagging behind in transposing the EU Directive 2018/2001 mentioned above: in facts, as we said, in Italy the only form of self-consumption allowed is from a single plant to a single final consumer (one to one), which means that the "prosumers" are not allowed to enter in the market to trade the electricity that has been produced.

However, the legislative model proposed above is applied in Italy in the Region Piedmont, which thus wins the title of forerunner in Italy in the legislation in the field of energy communities. The Regional Law of 3 August 2018, no. 12 "Promotion of the establishment of energy communities", has, in fact, outlined the disciplined regional framework of energy communities. According to Piedmontese legislation, municipalities wishing to set up an energy community are required to adopt a specific memorandum of understanding, drawn up based on criteria indicated by a subsequent regional implementation measure. Moreover, the Region, through *ad hoc* incentives and undertakes to financially support the phase of establishment of the energy communities.

At the same time, the Regional Law provides for the establishment of a permanent technical table between the energy communities and the Region, with the aim of acquiring data on the reduction of energy consumption, on the share of self-consumption and on the share of use of renewable energy.

Therefore, Piedmont is taking a first step towards the construction of a new model of virtuous territorial cooperation and the promotion of energy self-sufficiency. In our view, this attempt should be replicated by other regions and could be a stimulus to the national government for an adequate implementation of European legislation.

4. The Spread of Energy Communities in Italy

The number of initiatives currently being implemented in Italy on the subject of the Energy Community is limited. Nevertheless, according to a study by the Politecnico di Milano[56], has excellent potential for development. The limited number of initiatives, as we now know, is primarily, due to the fact that, within the current regulatory framework, Italy does not provide the definition of the Energy Community and on the basis of the current regulations, it is not possible to create new ones.

Anyways, there are two categories of plant configurations, appropriately defined and regulated, which can be traced back to the definition of Energy Community, the so-called Internal User Networks and historical Cooperatives. (Politecnico di Milano, 2014)

4.1 Four diffusion scenarios

The study assesses the potential for theoretical dissemination of energy communities in Italy and is estimated on the basis of the level of replicability of the Energy Community models previously cited, corresponded to an investment volume of about 500 billion euros, mostly referred to the residential and industrial sectors.

[56] Politecnico di Milano, Energy & Strategy Group, Smart Grid Report 2014.

Starting from these values, the study outlines four scenarios for the expected diffusion of Energy Communities in Italy, considering 2030 as the reference time horizon and based on:

(i) evolution of the regulatory framework, in terms of changes in the Energy Community models achievable in the electrical system and the roles and responsibilities of the various actors that are part of the energy system;

(ii) technological evolution, in terms of improvement of the technical-economic performance of technological solutions that have not yet reached a high degree of maturity (such as storage systems).

The most optimistic scenario, which considers a regulatory evolution favourable to energy communities in the short term and the achievement of cost and performance targets for technologies enabling energy communities, envisages the creation of almost 100,000 communities by 2030, for a total turnover of 160 billion euros (about 10 billion annually on average).

On the contrary, the most conservative scenario envisages the creation of a much smaller but still considerable number of Energy Communities, in the order of 25,000 units, for a turnover of approximately € 50 billion.

Among the variables at the base of the hypotheses of the scenario, the normative one appears to be the most significant. In fact, with the same technological evolution, a positive reform of the regulatory framework would make it possible to double the units of energy communities activated.

This potential is associated with rather significant systemic repercussions. In terms of costs incurred at the level of the electricity system - and therefore ultimately by all energy users - these could be reduced between 0.3 and 1 billion euros per year (equal to about 10-30% of the total incurred to date), based on the actual level of dissemination of the Energy Communities. Secondly, other important systemic benefits could be achieved, first of all the reduction of energy dependence from abroad, up to a value of about 10 billion €/year, equal to about one sixth of the current energy bill for imports and in line with the target set by the National Energy Strategy to 2020 (14 billion €/year).

4.2 Environmental Impact of Energy Communities

Another study[57], in order to analyse the impact of the Energy Communities in Italy, identify three diffusion scenarios: a "base" scenario equal to 5%, an "optimistic" scenario of 10%, and a "study" scenario of 15%, estimated:

- The contribution to national energy efficiency targets.
- The net economic impact for the members of the Energy Community.
- The effects on the electricity system.

These scenarios were calculated starting from the value provided by the Politecnico di Milano of a potential of almost 100 000 Energy Communities, of which about 80% in the residential area.

As far as the first element is concerned, the energy communities can be a tool for achieving high levels of energy efficiency.

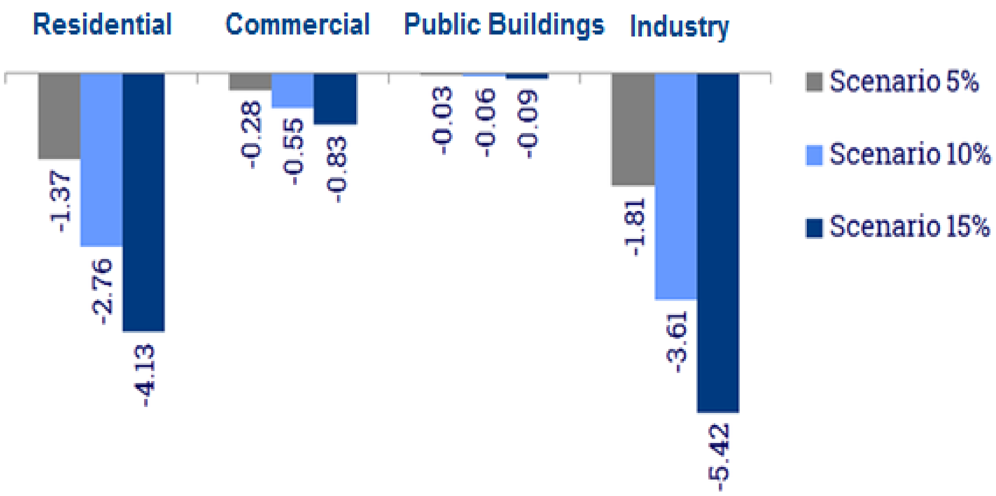
For example, by simulating the contribution to the energy saving objectives set by the “National Energy Strategy”[58], the spread of Energy Communities would make possible to achieve between 10% (in the 5% diffusion scenario) and 30% (in the 15% diffusion scenario) of the reduction-target. Particularly, the most appreciable benefits would be in the tertiary segment (with a contribution between 15% and 43% of the savings-target) and the industrial segment (between 12% and 36%).

[57] City Life Magazine – N. XXII – giugno 2016 di Lorenzo Tavazzi, Direttore Area Scenari di The European House – Ambrosetti e Pio Parma, Senior Consultant di The European House – Ambrosetti

[58] Parlamentare, A. Strategia Energetica Nazionale 2017.

On the environmental front, the lower CO_2 emissions, associated with the growing spread of Energy Communities could amount to a total of between 3.6 (in the 5% scenario) and 11 million tonnes per year (in the 15% scenario), especially in the industrial and residential segments.

Lower CO_2 emissions per sector (millions of tonnes/year) in the event of the spread of energy communities



Source: elaboration of The European House - Ambrosetti on data from the Politecnico di Milano, 2014

For the end users belonging to the Energy Communities, the economic benefit at an aggregate level can be quantified between 2 and 6 billion Euros per year, always taking as reference the gap between the penetration scenario at 5% and that at 15%.

Among the sectors, the impacts for the industrial sector are particularly appreciable: between 1.4 and 4.3 billion Euros per year.

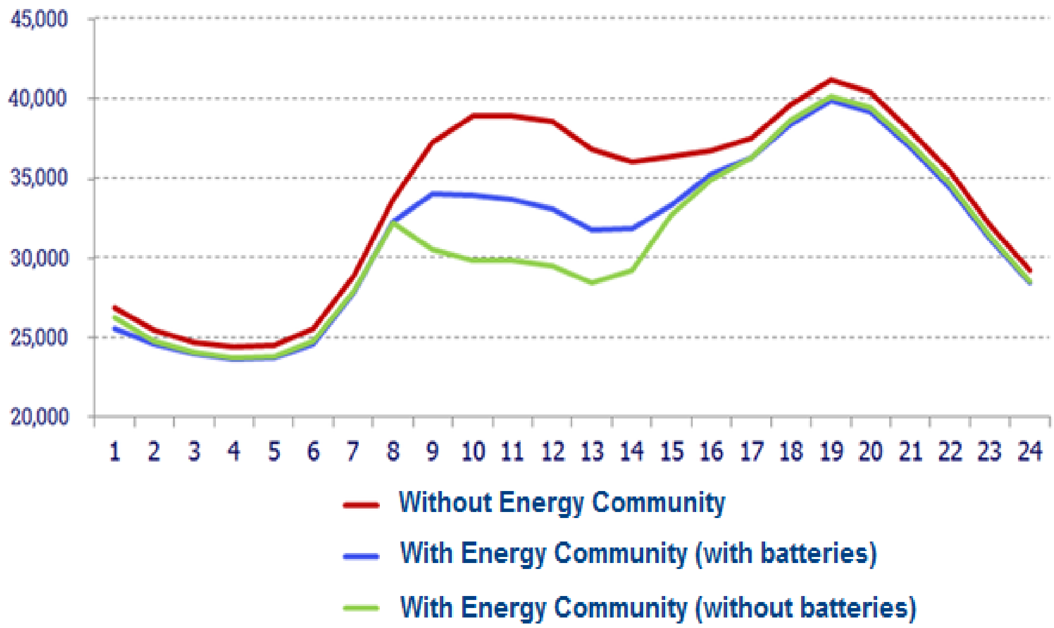
The Energy Community paradigm can also bring structural benefits to the electricity system in terms of:

1) Reduction of peak shaving during the day.

2) Load shifting to manage the load.

3) Reduction - in the presence of storage - of the variability of the impact of the Energy Communities on the operation of the power exchange. The effects are represented in the following figure.

Daily electricity demand on a typical day in Italy (MWh Assumed Energy Community scenario =5%, average hourly demand in the first 3 months of 2014)



Source: The European House - Ambrosetti on GME and Politecnico di Milano data, 2014

In order for this potential to be translated into concrete realizations, it seems necessary for the legislator to define a regulatory framework that promotes the dissemination of Energy Communities, taking into account the aforementioned benefits that their dissemination can achieve, while not neglecting the impacts of such dissemination on network operators. The latter, with particular reference to distribution network operators, would see as a consequence of the spread of the Energy Communities a decrease in the necessary network investments (and the related remuneration, established at regulatory level), in the order of € 20-100 million per year. On the other hand, as part of a more general re-design of the electricity system, they could take on a new role that benefits from the spread of the

Energy Communities. Such as assuming responsibility for dispatching activities at local level - i.e. the distribution network (now the responsibility of the transmission system operator) - including the energy flows exchanged with the Energy Communities.

IV. BLOCKCHAIN FOR ENERGY COMMUNITIES

1. Blockchain for Energy Communities

As we said several times now, the scope of this work is, on the one hand, pushing a faster acceptance by the Italian Parliament of the Renewable Energy Directive (RED II), and on the other, identify the blockchain technologies as the enabling technology par excellence when speaking about energy communities.

We have already seen the importance of a favourable legislative framework; here we will explore how actually the blockchain technologies can render energy communities a vast scale phenomenon.

There is no disagreeing that the blockchain technology is still a quite new-born model but if the knowledge acquired with blockchain in the financial industry is applied to the energy sector, the technology seems able of allowing a decentralized energy supply transaction system. It may be possible, for example, to drastically simplify today's system.

Different research institutes and start-ups, especially in the EU, believe blockchain technology could enable the 3D's: decentralization, decarbonization and digitalization of the electricity sector, while empowering prosumers. (Dobbenni et.al., 2017).

Nevertheless, according to Ernest and Young,

> *"A new ecosystem of energy blockchain start-ups is emerging, and venture capital, so far, has raised over US$1b to scale business models of the future. Aside from some early demonstrations, the applicability of an energy blockchain is largely theoretical. The ability to support a globally connected network of energy transfer, where smart devices will be able to securely send and receive data while autonomously reacting to market signals, is a reality some believe is still 5–10 years away. […] Huge investment is needed to digitize the grid, and global battery storage totals in the megawatts rather than gigawatts."*

However, the blockchain may have an impact on small scale energy communities, particularly, it is set to transform the energy sector through three ways:

1) Controlling energy networks through smart contracts.
2) Providing a decentralised storage of transaction data, increasing security and ensuring greater independence from a central authority.
3) Help to make payments via cryptocurrencies

In the following paragraphs we will explain each of those point.

1.1. Controlling energy networks through smart contracts.

Thanks to the blockchain technologies it would be feasible for energy communities to be controlled by smart contracts.

As we know, a Smart Contract translates contractual clauses into code, making it self-executing and self-enforcing, in a way that the need for trusted intermediaries between transacting parties would be minimized, as well as the occurrence of malicious or accidental exceptions. (Christidis, Devetsikiotis, 2016).

Through Smart contracts, thereby, the system would be able to recognize when there is the need to initiate any kind of pre-coded transaction.

For instance, in the case in which the energy generated exceed the energy needed, the smart contracts will guarantee that the excess of energy is conveyed directly into a storage system automatically, without the need of human interferences. Equally, the Smart Contract will deliver the energy to another facility in which the energy needed exceed the energy generated, eliminating any need to store the energy at all.

Correspondingly, the stored energy would be re-organized for use every time the produced energy is scarce. In this way, blockchain technologies will directly control network flows and storage facilities, resulting in tremendous cost and time reductions.

1.2. Providing a Decentralised Storage of Transaction Data, Increasing Security and Ensuring Greater Independence from a Central Authority.

In addition, blockchain enabled smart contracts can enable records to be documented in a proofed manner on the blockchain. The use of distributed ledgers will secure the record of all the transactions and will document all activities.

As we explained in the chapter entitled "The Blockchain Technologies", this technology provides a more secure way of recording property rights and other transactions since the records are proofed and accessible in a transparent way to everyone.

Being proofed, transparent and decentralized, blockchain opens a wide range of new opportunities for energy communities, as in the scope of this work, but also for energy certifications. These two things, sometimes, as we are going to see in the chapter "Blockchain Energy Models" can go hand to hand. Anyways, the main two application of this decentralized storage of data are:

1) Emission trading, verification of renewable electricity and emission allowances: blockchain would provide a safer and faster way of managing certificates for renewable power and emission allowances.

2) Asset ownership and management: the energy sector could take advantage from blockchain through having a blockchain based register that records and regulates the existing state of assets as well as their ownership (asset

management). Such assets can include, for example, smart meters, the electronic device that records consumption of energy and delivers the information to the supplier).

In this way, energy communities, having been provided by a system that is able of ensuring that property rights and other transactions are recorded automatically in a proofed, transparent and decentralized manner, are able to achieve high levels of independence from a central authority. Also, in this case the cost cutbacks are significant.

1.3. Customers could use cryptocurrencies to pay for the energy supplied.

Beside the possibility of leveraging cryptocurrencies to fund the actual construction of energy communities thought the use of Initial Coin Offerings (ICOs), cryptocurrencies can also serve the scope of enable the actual energy transaction among peers. In this system, as we are going to see better in the following chapter, the grid's smart contract takes as input the cryptocurrencies and then releases the energy that corresponds to that amount of cryptocurrency received.

2. New Ways of Financing

As well known, the main types of financing for companies can be summarized in the following types: loans proposed by banks and other financial intermediaries; issue of bonds and capital.

Nevertheless, banks and non-banks tend to prefer to lend money to established companies, with stable and positive historical cash flows, especially if they can provide collateral or personal guarantees.

Those characteristics are generally absent in start-ups, namely those new businesses that intend to grow beyond the solo founder, have employees, and intend to grow large, but that are still in a dimension of trial and error, that is the experimentation of the business model and the optimal strategy.

Hence, start-ups usually have a very high-risk rate because there are many variables that affect the business and different scenarios that may arise. These companies are characterized, moreover, by a low survival rate. On the other hand, they can lead to an extremely high level of earnings if they are successful.

Conversely, SMEs are businesses whose personnel numbers fall below certain limits.

They are usually characterized by a family type of management, where the founding member is also the owner of the majority of the shares of the company, as well as administrative manager, supported by other members of the family, usually placed in the key roles of the company organization chart without having the background and training needed to match their role. Moreover, for these companies there is generally no CFO (Chief Financial Officer) able to guide the company in choosing the appropriate financial instruments to be adopted and in choosing the best debt ratio.

By their very nature, start-ups lack of historical records: all they have is a document of a preventive type or a prospectus that serves to determine the convenience of the business project by identifying costs and revenues and, therefore, determines the profit of the future activity.

Conversely, SMEs produce accounting documents on a regular basis, even if there is a huge difference if the company is obliged to draw up the financial statements in a standard or abbreviated form. In the second case, the absence of many items in the balance sheet clearly limits the content of information.

For those reasons, usually, start-ups and SMEs find difficult to receive founding and, when they do, its price it is often very high, or higher that the founding provided to more stable or bigger companies.

We can draw a parallelism between the difficulties found by start-ups and SMEs in finding external sources of financing and the difficulties that can be found by energy communities, mostly because of the lack of info.

Indeed, the determination of prices depends not only on the general level of interest rates, but also on the type of activity to be financed, the sector in which the provider operates, the nature of any guarantee, the type of financial instrument, the legal structure of the company.

In general, a lender will seek signals that demonstrate a commercially successful track-record, sound financial management and good chances of continued success.

Unquestionably, even if some lenders choose to avoid all companies in the start-up phase, there are forms of founding such as angel investors or forms of non-banking such as loan funds, crowdfunding platforms, leasing companies, community financing organizations and large companies that provide loans to businesses in various forms and ways.

In this context Blockchain assumes a relevant importance in spurring the possibilities for innovative start-ups to scale up and grow.

In facts, lately, a new form of founding using cryptocurrencies, the most exploited form of Blockchain, has spread.

We are talking about the ICO, initial coin offering.

This new kind of financing has spread so much that it is estimated that until 2017 ICOs raised as much as $5.3 billion around the world. For comparison, in 2016, venture capital invested $71.8 billion in the United States and $4.3 billion in Europe. (National Venture Capital Association and Invest Europe).

Therefore, even if the 2018's data show a strong restriction of these operations, it is impossible to don't consider this instrument as an alternative to the collection of fresh funds, especially for start-ups and SMEs.

Its advantages are especially found in the fact that it does not require the presentation of any document to demonstrate the reliability of the company and in the fact that, by selling the tokens, no shares in the company are sold.

Nevertheless, in the case in which the star-up fails, the only ones to lose are lenders and investors.

Hence, the blockchain technologies, beside let energy communities achieve the coveted characteristics explained above, can help further with their financial uses.

The possibility that energy communities will make an extensive use of these "bottom-up" ways of funding is backed, in our opinion, by the fact that among the sources of financing for companies that develop goods and services of a social nature, crowdfunding has a prominent place.

As a matter of fact, the application of crowdfunding models in the energy sector has increased with the evolution of energy markets.

Well-known crowdfunding portals, such as Kickstarter and Crowdcube, raised a total of $3.4 billion and $483 million, respectively, from their establishment up to December 2017 (source: platform web sites)[59].

The liberalisation of markets, the strengthening of networks and storage devices, the implementation of intelligent technologies, the introduction of the prosumer figure, are elements that have favoured the spread of crowdfunding platforms dedicated to energy.

[59] Why do businesses go crypto? An empirical analysis of initial coin offerings Saman Adhamia, Giancarlo Giudicib,⁎, Stefano Martinazzib aBocconi University, Milan, Italy bPolitecnico di Milano, School of Management, Milan, Italy

2.1 Crowdfunding

Crowdfunding is a way of raising funds through online platforms and based on a public call to contribute. It is a phenomenon born from the bottom in the years of the economic crisis due to the need to identify new sources of financing, given the restriction of bank credit[60] (ESMA 2015, EU Commission 2015, UNEP 2015), and which has assumed considerable dimensions over the years, becoming an important resource for start-ups and new businesses, especially innovative ones. The global market for alternative sources of finance reached a value of more than €250 billion in 2016.

Crowdfunding projects can be classified according to the model of involvement and the expected benefits for the donor/investor. The various types can be simplified into two major types, which are distinguished on the basis of the relationship between the provider and the recipient of funding. Therefore, we can separate non-financial crowdfunding (or donation crowdfunding), if contributors do not get a financial return from the donation, from financial crowdfunding (or investment crowdfunding), where on the contrary the donation is combined with the sale of financial instruments that provide a return.

Blockchain technologies can be integrated into crowdfunding, spurring the development of energy communities. What are the reasons of integrating the blockchain into crowdfunding?

[60] ESMA 2015, EU Commission 2015, UNEP 2015

A blockchain based crowdfunding platform would manage the funding through smart contracts, this would make the whole process more transparent, quicker and less costly.

Traditional crowdfunding platforms, in facts, take a large percentage of the profits as a fee. For instance, two of the most famous crowdfunding platforms, Kickstarter and Indiegogo charge, respectively, a 5% fee to the funds collected plus a 3-5% payment processing fee (Kickstarter); and a 5% fee to the funds collected plus a payment processing fee that varies according to your location and currency (Indiegogo).

Decentralization, achieved through blockchain, in the ways we had seen in the previous chapters, remove the intermediaries allowing the different parties involved in the process to directly communicate with each via smart contracts. Hence, removing the fees that are now commonly applied.

Another positive effect that blockchain based crowdfunding platform can help achieve is ensuring backer protection.

In facts, the backers, thanks to smart contracts, will be able to verify if the milestone had been met through a democratic vote. If the milestones are not met, then the backer insurance funds are refunded to the backers directly through the smart contract. Otherwise, it is credited to the creator.

2.2 Initial Coin Offerings

Initial Coin Offerings (ICOs) can be defined as open calls for funding promoted by organizations, companies, and entrepreneurs to raise money through cryptocurrencies, in exchange for a "token" that can be sold on the Internet or used in the future to obtain products or services and, at times, profits[61].

For a start-up that want to raise money through an Initial Coin Offering the process is relatively easy. The typical pattern is to produce a white paper that describes their business model and technical approach. The white paper includes details about the functions that the tokens issued during the ICO will perform and the process of token creation. […] The tokens are then offered for sale in an auction, and the proceeds are used to fund the project[62]. (Conley, 2017)

ICOs share several features with the crowdfunding mechanism: low contributor protection, limited information, no supervision by public authorities and no relevant track record for proponents are the most important issues in common between the two systems. There is a main difference though: meanwhile crowdfunding portals collect fiat money through traditional payment channels, ICOs rely on cryptocurrency Blockchains, offering their own token.[63] (Adhami, Giudici, Martinazzi, 2018)

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[61] Why do businesses go crypto? An empirical analysis of initial coin offerings Saman Adhamia, Giancarlo Giudicib,⁎, Stefano Martinazzib aBocconi University, Milan, Italy bPolitecnico di Milano, School of Management, Milan, Italy

[62] Blockchain and the Economics of Crypto-tokens and Initial Coin Offerings1 John P. Conley2 Vanderbilt University June 2017

[63] Adhami, S., Giudici, G., & Martinazzi, S. (2018). Why do businesses go crypto? An empirical analysis of initial coin offerings. Journal of Economics and Business, 100, 64-75.

ICOs share also several features with the more traditional Initial Public Offerings (IPOs), where shares of the company are sold. However, also between ICOs and IPOs we find a profound difference. Meanwhile in a IPO who fund the company buys shares of it, becoming an actual owner of the company which receives dividends and have the right of vote, in a ICO the investor simply buys the token and he can just hope that the company becomes successful in order to see the value of the tokens raising. *(*Hoang, 2007)[64]

Last but not least, another important aspect that we should take into account when evaluating an ICO is the fact that several online services, such as Token Factory, allow the creation of cryptocurrency tokens with an extremely short amount of time. Joining this concern with the recalled above one that usually little information is shared, it is easy understandable the high risk of frauds.

According to a study conducted by New York-based Satis Group LLC, in facts, about 80% of ICOs are frauds. Incidentally, according to data about the 2017 among the 435 successful ICOs (each raising an average of $12.7 million for a total amount raised of $5.6 billion) the 10 largest projects raised 25% of this total, making many investors millionaires.

[64] Hoang, P. (2007). 1.4 stakeholders. Business and management, 71.

3. Blockchain Energy Models

We saw what an energy community is in theory; we also explained why the blockchain technologies may be considered enablers of such communities. Here we are going to present the systems of energy community possible, under a design point of view, in which the blockchain technologies may play a role.

Once the energy produced leaves the prosumer's house it can be either be saved in a central neighbourhood energy storage or be directly sent to the consumer.

In the following two chapters we are going to see explain these systems in detail.

3.1 Neighbourhood Central Storage

In this system, the energy produced is sent to a central storage and is stored until a consumer request it. In order to better understand how this system actually works, it is important to understand the different levels in which the system is organized.

Its structure can be summarized pinpointing three key components

- the energy grid,
- the middleware controller,
- the smart contract.

When the energy is sent to the central storage, a smart meter connected to every prosumer measures the amount of energy that has been inserted.

Smart meters, together with the software that handles their output – for example a middleware controller – are the input for our smart contracts.

When a predefined amount of energy has been delivered to the storage system, a cryptocurrency token is awarded to the prosumer.

In this system, hence, the blockchain technologies came into place providing cryptocurrencies to pay for the energy supplied, as we saw in one of the chapters above, and enabling the transaction security and automaticity through the use of smart contracts.

The middleware controller connects the central storage with the smart contract.

The energy grid knows the entities connected to it and it can transfer a defined quantity of energy to them. Moreover, it is also aware, in every moment, of how much energy for consumption is accessible.

The grid's smart contract takes as input the cryptocurrencies and then releases the energy that corresponds to that amount of cryptocurrency received.

The way in which this kind of cryptocurrencies can circulate in the market is subjected on their owners' interests and strategies. The easiest way would be trading these cryptocurrencies with another currency, cryptocurrency, assent, financial instrument or commodity directly with a smart contract.

3.2 Direct Energy Exchange

Here, the consumer receives energy from the producers in a direct manner, without relying on a central energy storage like in the system described above. When the consumer asks for energy, the smart contract automatically check whether the demanded energy is available. If this is the case, it will forward to the producers the request of the consumer.

After that, the automatic negotiations between the consumer and the producer take place. The producers can have either a fixed price or a price indicated by supply and demand.

In any case, these contract negotiations are automated and carried out by smart contracts that will find an ideal compromise. The advantage of using smart contracts lies on the fact that smart contracts are immutable and can be seen by everyone. Hence relying on a smart contract, the parties can be sure that the conduct of the negotiation will always be transparent and predictable. Once the price has been agreed both parties digitally sign the agreement, always through a smart contract, and the money that will be involved in the transaction is sent to a predefined address that functions as an escrow account. All what remains to do is to perform the exchange of energy. As before, it is the middleware controller to handle the exchange of energy.

In this direct energy exchange with the use of a smart contract, differently from the system described above - where the producer receives the cryptocurrency as a payment for the quantity of energy delivered to the central storage system – the producer is paid directly by the consumer. Nevertheless, the payment can consist of:

i) the two sides complete the transaction with the use of a third means of payment (e.g., Euro, Bitcoin, Ether, etc.)
ii) Demand energy voucher are sold *a priori* to the interested consumers that afterwards can convert them.

3.3 Blockchain Enabled Automatic Energy Detection from Neighbour Nodes

In the two systems described above, energy mapping is measured by smart meters.

Smart meters are the entities that measure every outgoing and incoming energy. The actions of the middleware controllers rely on the mart meter's measurements. As we may easily imagine these systems have to be accepted by all parties and more significantly cannot be easily verifiable. In facts, it is hard for a user of the system to know certainly whether the smart meters have been tampered. It is here that the blockchain technologies came into place proposing what we support to be its most important feature for the energy sector and the spread of energy communities. In order to enhance trust within the system, the energy detection can be done from neighbour smart meters, acting like nodes of a blockchain. In practice, whenever a producer injects energy in the grid its neighbour nodes detect the injected energy and validate it using one of the consensus mechanisms described above.

V. CONCLUSIONS

Blockchain is a digitized, distributed and decentralized ledger database that stores a registry of assets and transactions across a peer-to-peer network. It is, basically, a public registry of who owns what and who transacts what.

The features that characterize this technology are particularly feasible to achieve cost reductions; trust among untrusted parties; transparency and proofed data storage.

Even if the discussion about whether the blockchain can be labelled as a General Purpose Technology is still open - since it is a relatively young technology - we succeeded in supporting the idea that it can be seen as the enabler par excellence for P2P energy trading and, therefore, for energy communities.

Throughout this work, in facts, we explained the several different ways in which this technology may have an impact, namely, controlling energy networks through smart contracts, providing a decentralised storage of transaction data, increasing security and ensuring greater independence from a central authority; and giving the possibility to customers to use cryptocurrencies to pay for the energy supplied.

Moreover, producers, consumers and prosumers will also have more information on their energy usage and costs using blockchain-based smart contracts and will be able to easily sell or buy more energy depending on their usage at any given time.

Blockchain’s application in the financial sector then may be useful, furthermore, to finance energy communities through blockchain backed crowdfunding platforms and ICOs.

The liberalization of the energy sector, then, also offers a business opportunity for third-party providers of smart grids.

During this work we showed how the structure of the energy system and generation from renewable resources in Europe and Italy seems favourable for the creation of Renewable Energy Communities, energy communities in which the energy traded comes exclusively from renewable sources.

In the creation of such communities, certainly, the “Clean energy for all Europeans" regulatory package, launched by the European Commission in November 2016 and the new Renewable Energy Directive (RED II) will play a huge role. The RED II, in facts, represent the first legal recognition of self-consumption and energy communities.

Nevertheless, policymakers may still play a role in the transaction to an energy system characterized by renewable energy communities and self-consumption.

On the one hand, since the blockchain technologies are still an almost new-born technology, their intervention would be needed in order to fuel trust on these technologies and building bridges across the community of blockchain innovators. On the other hand, policymakers’ intervention would be needed in order to incentives the creation of start-ups and companies able to provide smart grid solutions, enabling P2P energy transactions.

In order to spur such project in our view would be particularly relevant the issuing of grants, as well as the designing of proof of concepts (POC) and Pilot Projects.

Policymakers' intervention is even more important in realities such as the one in Italy. The Italian legislation framework, in facts, does not recognize energy communities, despite the RED II, and the only form of self-consumption allowed is the exchange from a single plant to a single final consumer (one to one), with the remission into the grid of the excess of energy produced. The aim of this work, as we said several times now, is also to push a faster acceptance of the RED II by the Italian Parliament.

The discussion about the need for the European Union to enforce to member States its energy sector's legislative framework in ways that are different then the process of European directives is left to future works.

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